INTERNATIONAL ACOUSTICS RESEARCH ORGANIZATION

Brief Review and Commentary on the Study conducted by Landesanstalt fur Umwelt Baden-Wurttemberg:

"Low-frequency noises including infrasound from wind turbines and other sources",

published in February 2020 using data collected in 2013-2015.

October 2020

International Acoustics Research Organization

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A. BACKGROUND

As leading experts on the biological response to infrasound low frequency noise exposure, we were requested by the Belgian Association *KLAP! vzw* to provide a review of the Feb 2020 Report, prepared by the Landesanstalt fur Umwelt Baden-Wurttemberg (LUBW — State Institute for the Environment of Baden-Württemberg), and based on data collected from 2013-2015: "Low-frequency noises including infrasound from wind turbines and other sources". This report is in German.

Additionally, we have been provided with the CSD Ingenieurs report, "Bassilly Wind Power Station Project Permit Request — Environmental Impact Assessment", specifically Annex N which translates the Summary of the above-mentioned LUBW report. This Summary is in French.

Since neither French nor German are languages spoken by the authors, an internet machine translator was used to produce the LUBW summary (pages 9-12) English. This is included herein as Annex 1. All quotations from the LUBW Report will refer to the text contained in Annex 1.

The data used in the LUBW report was collected in 2013-2015. Significant scientific advances have been made in the field of acoustic data acquisition and, hence, **these data may be rather antiquated**. As fellow scientists, we empathize with the fact that the resolution of the acquired data is always limited by the type of equipment available, and that the authors of the LUBW Report were necessarily restricted by the prescriptions of the German Regulation DIN 45680.

Given the ultimate purpose of this Review, associated with the Bassilly Wind Power Station Project Permit Request, these authors have decided to focus mostly on the data obtained in the vicinity of wind turbines, as documented in the LUBW Report.

Disclaimer

a. The authors of this review are not party to anti-technology sentiments;

b. Wind turbines are considered by the authors as welcome additions to modern technological societies;

c. The review provided herein has one, and only one, agenda - that of pure scientific inquiry;

d. In no way can or should this scientific review be construed as a document arguing for or against the implementation of wind turbines, or any other industrial complexes;

e. There are no commercial, financial or professional agreements (contractual or otherwise) between the authors of this Review and any persons or parties involved in the wind turbine sector or persons or parties who stand against the implementation of wind turbines;

f. This Review was provided *pro bono*.

Goal

To provide a scientific review of the LUBW Report, within the authors' areas of expertise and, therefore, exclusively focused on the evaluation of infrasound and low frequency noise and the potential health hazard they pose to human health.

B. "WHAT YOU CAN'T HEAR WON'T HURT YOU…"

1. The use of the:

    - dBG frequency-weighting system,
    - dBA frequency-weighting system, and
    - comparative analyses with the human hearing threshold levels,

    is a direct indication that the study is based on the erroneous, yet prevalent, assumption: *what you can't hear won't hurt you*.

2. The Russian Federation has legislation for permissible infrasound levels (<20 Hz, considered inaudible to humans) since 1970's. See Figure 1.

Premise	Sound pressure levels, dB, in octaval bands of averaged geometric frequencies, Hz				General sound pressure level dB "Lin"
	2	4	8	16	
Different jobs inside industrial premises and production areas:					
- Different physical intensity jobs	100	95	90	85	100
- Different intellectual emotional tension jobs	95	90	85	80	95
Populated area	90	85	80	75	90
Living and public premises	75	70	65	60	75

Figure 1. Permissible exposure levels for infrasound legislated in the Russian Federation[1].

3. French scientists[2] have shown that ***genetically deaf*** mice have decreased swimming performances when exposed to infrasound.

4. Scientists in the United States have shown that workers who used ear protectors still develop extra-auditory pathology when working in noisy environments[3].

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1 In: Stepanov V. (2000) Biological Effects of Low Frequency Acoustic Oscillations and their Hygienic Regulation. State Research Center of Russia, Moscow. https://apps.dtic.mil/dtic/tr/fulltext/u2/a423963.pdf

2 Busnel RG, Lehmann AG. (1978) Infrasound and sound: Differentiation of their psychophysiological effects through use of genetically deaf animals. Journal of the Acoustical Society of America, 63:974-77.

3 Cohen A. (1976) The influence of a company hearing conservation program on extra-auditory problems in workers. Journal of Safety Research, 8: 146-62.

5. Portuguese scientists have shown that infrasound and low frequency noise is a genotoxic agent, with implications for teratogenesis (birth deformations) and mutagenesis (onset of malignant tumours)[4,5]

6. Chinese scientists have demonstrated that infrasound exposure causes neuronal damage in specific regions of the brain, leading to memory and learning impairment[6,7,8].

7. Clearly, the notion *what you can't hear, won't hurt you* is scientifically indefensible.

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[4] Silva MJ, Carothers A, Castelo Branco NAA, Dias A, Boavida MG. (1999) Sister chromatid exchanges workers exposed to noise and vibration. Aviation, Space & Environmental Medicine, 70 (3, Suppl): A40-5.

[5] Silva MJ, Dias A, Barreta A, Nogueira PJ, Castelo Branco NAA, Boavida MG. (2002) Low frequency noise and whole-body vibration cause increased levels of sister chromatid exchange in splenocytes of exposed mice. Teratogenesis, Carcinogenesis &. Mutagenesis, 22(3): 195-203.

[6] Yuan H, Long H, Liu J, Qu L, Chen J, Mou X. (2009) Effects of infrasound on hippocampus-dependent learning and memory in rats and some underlying mechanisms. Environmental Toxicology and Pharmacology, 28: 243-7.

[7] Shi M, Du F, Liu Y, Li L, Cai J, Zhang GF, *et al.* (2013) Glial cell-expressed mechanosensitive channel TRPV4 mediates infrasound-induced neuronal impairment. Acta Neuropathologica, 126: 725-39.

[8] Zhang MY, Chen C, Xie XJ, Xu SL, Guo GZ, Wang J. (2016) Damage to hippocampus of rats after being exposed to infrasound. Biomedical and Environmental Sciences, 29: 435-42.

C. MEASUREMENT CONSIDERATIONS

1. It is understood that the goal of the LUBW Report was to "collect current data on the occurrence of infrasound (from 1 Hz) and low-frequency noises in the vicinity of wind turbines and other sources" (page 2). (All quotations of the LUBW Report refer to the English summary provided in Annex 1, unless otherwise indicated.)

2. It is also understood that ***it is not the goal*** of the LUBW Report to evaluate the biological significance of the infrasound levels that were detected, with the exception of comparing them with the classically established levels of the human hearing threshold.

3. Therefore, the interest of the LUBW Report was the quantification of the emissions of Infrasound (<20 Hz) and Low Frequency Noise (<100 Hz) (ILFN) from wind turbines (WT), *and not*, the quantification of a physical agent of disease. If it were the latter, measurements would, necessarily, also be made *in the homes* in the vicinity of WT, and additional physiological parameters and person-to-person interviews would have to be obtained.

4. For the WT measurements, it is stated that the microphones were placed at 100 m, 300 m, and 700 m from the tower. Wind turbine acoustic signatures (see below) have been detected at 9 km from the nearest tower by Australian scientists[9], and 50 km away from the nearest tower by Finnish scientists[10]. Given the large wavelength of the ILFN phenomena (from 343 m at 1 Hz, to 17 m at 20 Hz[11]) that are relevant for health considerations, it would seem pointless to have such small spacing in between measurement points. Moreover, the rate of infrasound dissipation in the air is approximately half that of audible sound.

[9] Flinders University, Austrália (2019). https://news.flinders.edu.au/blog/2019/06/19/wind-farm-noise-recorded-almost-9km-away/

[10] Aunio Group, Finland (2017). https://www.auniogroup.com/2017/09/11/infrasound-from-wind-turbines-is-a-new-signal-in-the-environment/

[11] Numbers are approximate and refer to airborne propagation of acoustics pressure waves.

D. DATA ANALYSIS CONSIDERATIONS

1. The LUBW Report states:

> *"Below 8 Hz, **discrete lines appear in the frequency spectrum**, which can be traced back to the uniform movement of the individual rotor blades" (Annex 1, page 4).*

2. Presumably this relates to the discrete horizontal lines in the following sonogram below, roughly, 8 Hz.

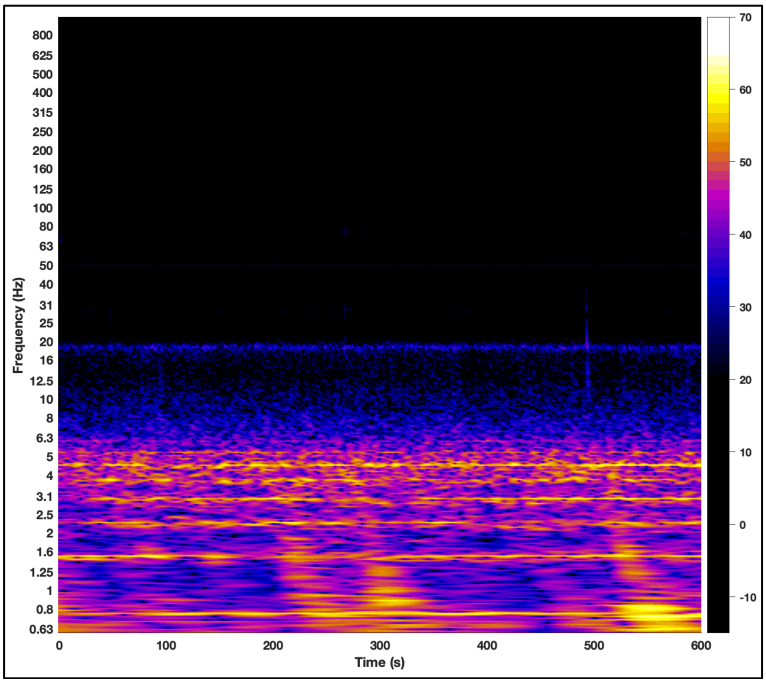

Figure 2. Sonogram of the acoustic environment inside the Master Bedroom of a home located in the vicinity of WTs, from 04:00 to 04:10, on 29 July 2020. At 05:00, the male home-owner was compelled to take medication (see text)[12].

3. These "discrete lines" are related to the WT acoustic signature and are pointed out in the 1/36-octave band periodogram in Figure 3. The attributes of this acoustic signature depend on the manufacturer's specifications for the WT, specifically the blade pass frequency.

[12] These and other data from this case are currently under the process of scientific publication and have been submitted as evidence in Court Proceedings.

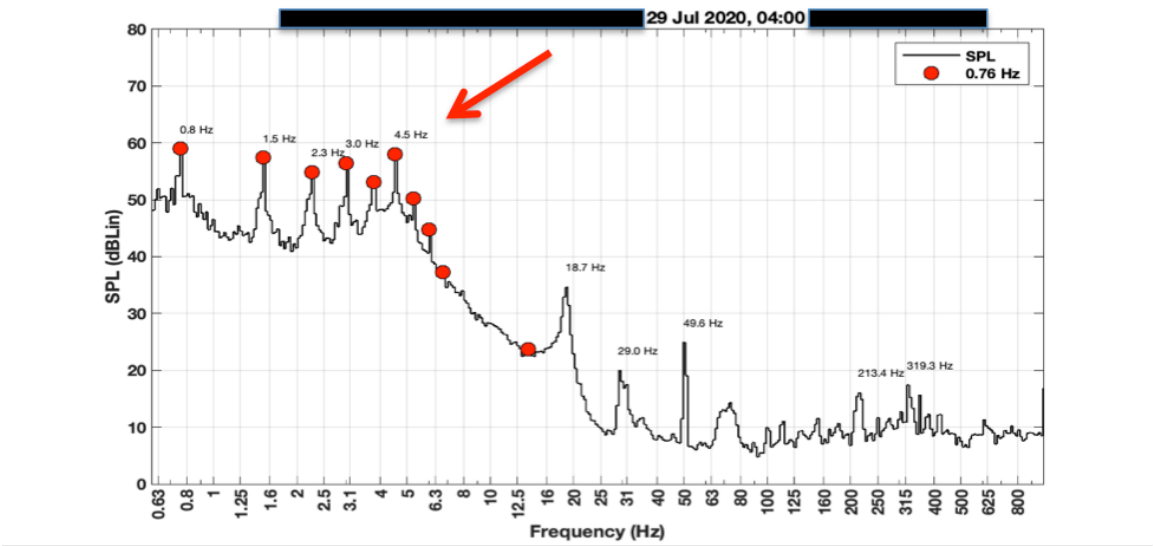

Figure 3. Periodogram of the same data sample as shown in Figure 2, inside the Master Bedroom from 04:00 to 04:10, on July 29th, 2020. The arrow points to the peaks in the levels of acoustic energy, collectively known as the **wind turbine acoustic signature**. The frequencies at which these peaks occur are exactly the same as those at which the "discrete lines" occur in the sonogram above, and depend on WT manufacturer specifications (blade pass frequency).

4. The sequence of peaks of elevated acoustic energy that are pointed out in Figure 4 constitute a WT acoustic signature (i.e., the values of the frequencies at which the peaks occur fall on a harmonic series, where the fundamental frequency is the blade pass frequency given by WT manufacturers).

5. In this particular home, from 03:00-06:00 on 29 July 2020, the WT acoustic signatures were present 100% of the time.

6. On the morning of 29 July 2020, at 5:00, the male home-owner of the master bedroom felt compelled to take medication (benzodiazepines).

7. For comparison, Figure 4 and Figure 5 show examples of the absence of the WT signature, in the same master bedroom, on 22 July 2020, from 04:00-04:10.

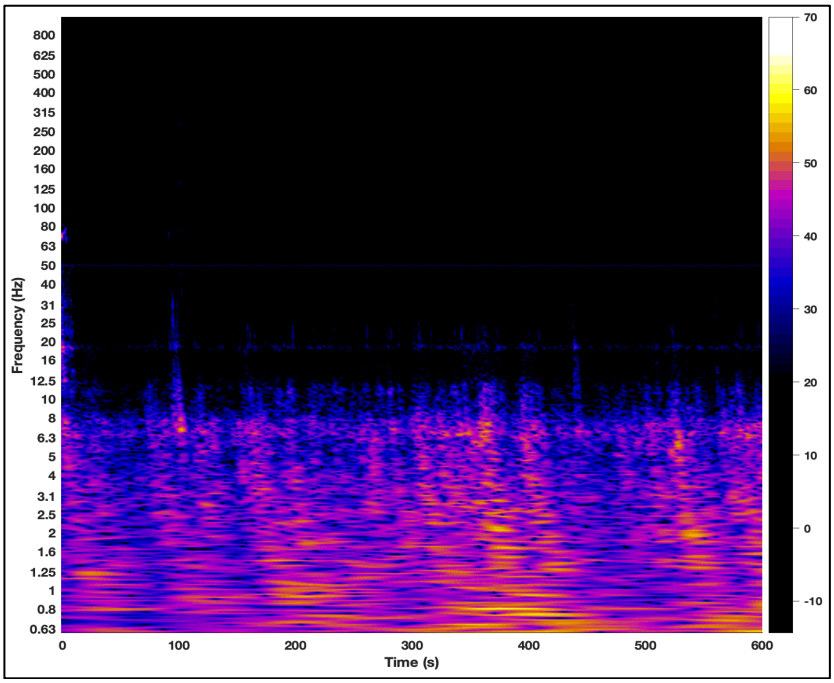

Figure 4. Sonogram of the acoustic environment inside the Master Bedroom of a home located in the vicinity of WTs, from 04:00 to 04:10, on 22 July 2020. No discrete lines are present. This morning the couple slept very well and woke up late.

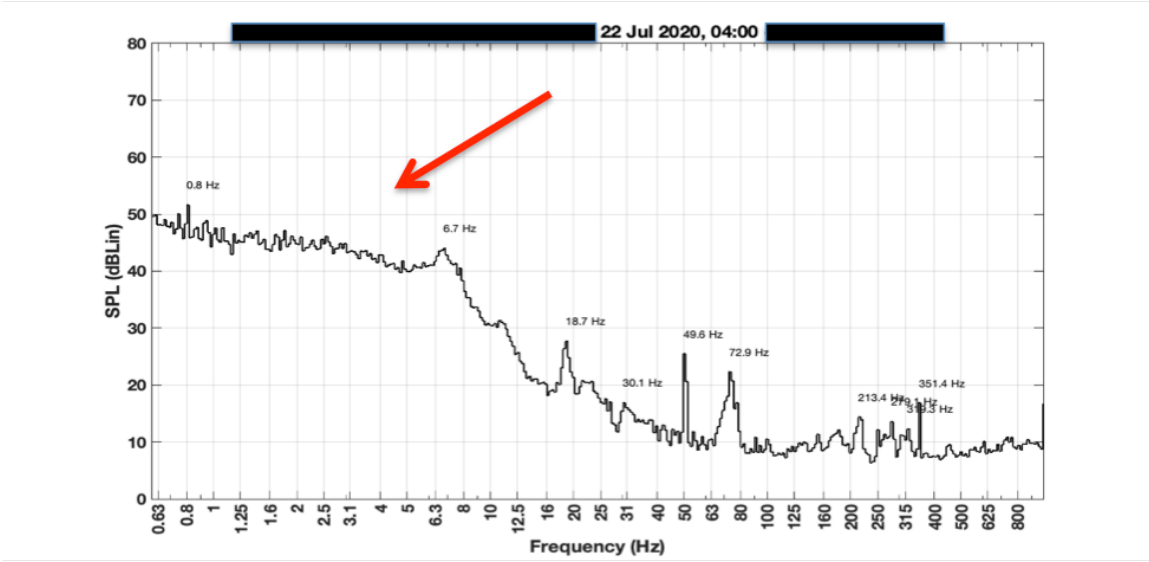

Figure 5. Periodogram of the same data sample as shown in Figure 4, inside the Master Bedroom from 04:00 to 04:10, on 22 July 2020. The arrow points to the absence of WT-associated peaks of acoustic energy levels, i.e., WT acoustic signatures are absent. On this morning, the couple overslept.

8. In this particular bedroom, from 03:00-06:00 on 22 July 2020, WT acoustic signatures were absent 100% of the time.

9. On the morning of 22 July 2020, the couple slept very well, and even overslept.

10. Figures 2-5 above are based on analyses that have a frequency resolution of 1/36 octave, a temporal resolution of 1 second, and acoustic energy levels that are expressed solely in dB Linear.

11. For comparison, the same data is shown with the ⅓-octave resolution (used in the LUBW Report), and with acoustic energy levels expressed in both dBA (used in the LUBW Report) and in dBLinear (also used in the LUBW Report).

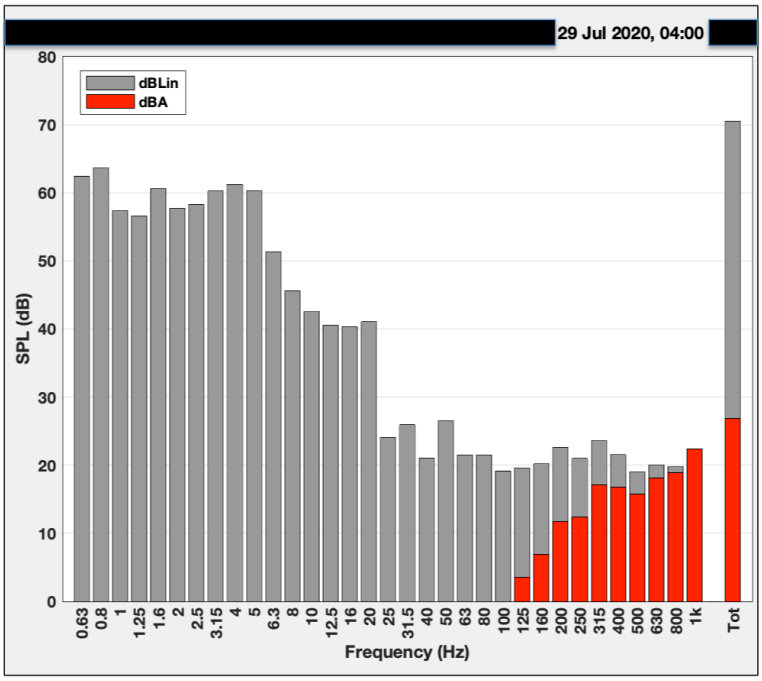

Figure 6. ⅓-octave band analysis for 29 July 2020, from 04:00-04:10, in the Master Bedroom on the night when the man felt compelled to take medication at 05:00.

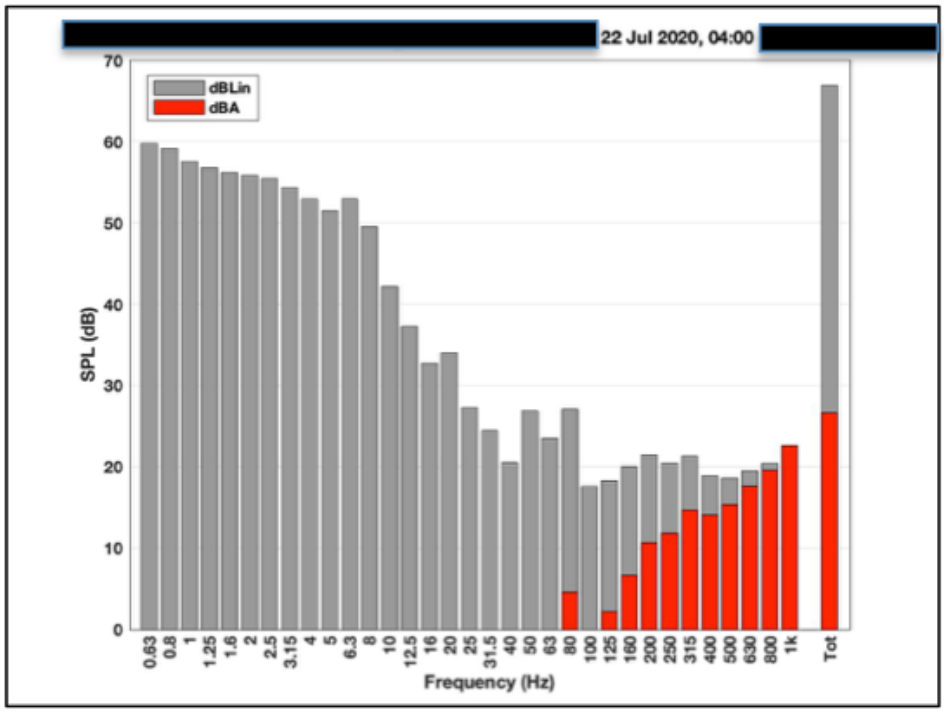

Figure 7. ⅓-octave band analysis for 22 July 2020, from 04:00-04:10, in the Master Bedroom on the night when the couple slept very well.

12. As can be readily discerned by visual inspection of Figure 7 and Figure 8, in the presence or absence of WT signatures, the dBA and dBLin levels under ⅓-octave analyses hardly differ. The slight increase in the dB Linear values (grey bars) is easily confused with increased winds.

13. The resolution of a ⅓-octave band analysis is insufficient to identify WT acoustic signatures. The increase in the acoustic energy levels (grey bars in Figure 7) can understandably be misinterpreted as wind.

14. Hence the statement made in the LUBW Report, which can now be understood as (not wilfully) **erroneous and misleading**, and that reads:

> *"During the measurements at a distance of 700 m from the wind turbines, it was observed that when the system was switched on, the measured infrasound level no longer increased significantly or increased only slightly. **The infrasound was mainly generated by the wind and not by the systems**" (Annex 1, page 5)*

E. ACOUSTIC ENERGY LEVELS EXPRESSED IN dBG

1. For the group of scientists authoring this Review, expressing energy levels in dBG is scientifically uninteresting and highly misleading because dBG only quantifies infrasound with zero weighting at 2 distinct points along the spectrum: 10 Hz and 31 Hz.

2. Figure 8 illustrates the severe limitation of the G frequency-weighting, if the objective is to quantify the amount of ILFN present in the environment.

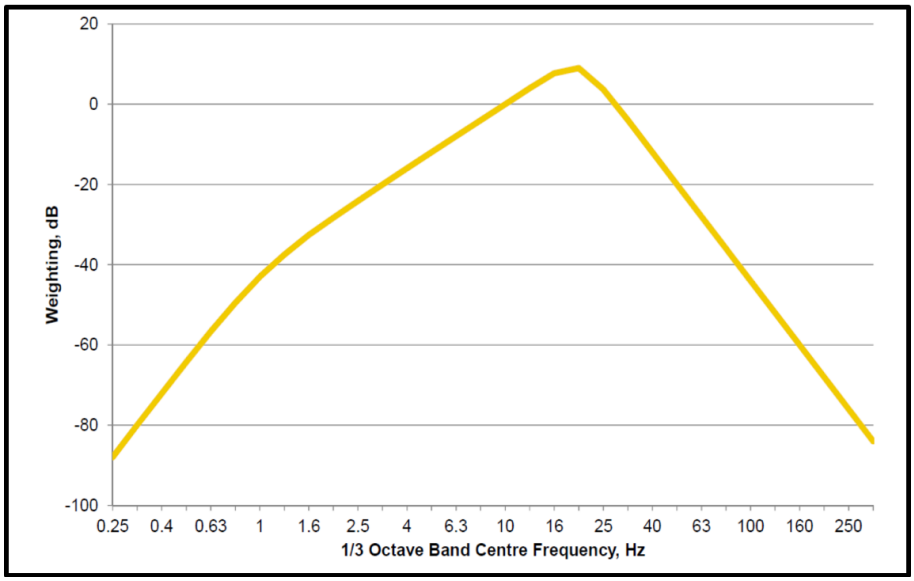

Figure 8. Frequency response curve for the G-frequency-weighting.

3. Figure 9 further illustrates the inadequacy of the G-frequency-weighting if the purpose is to quantify and characterize an acoustic environment, particularly one that may have implications on human health.

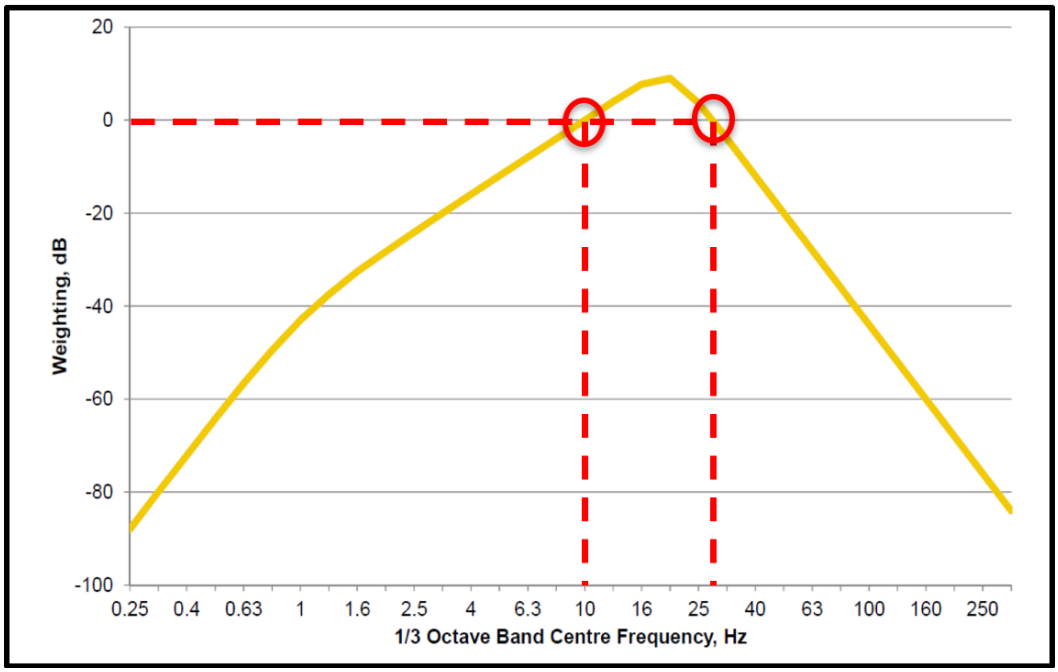

Figure 9. The red lines indicate which frequencies correspond to 0 weighting. As can be seen, only 2 frequency points on the curve have a corresponding dB weighting of zero: 10 Hz and 31 Hz. This means that the measurements of acoustic energy levels taken at all other frequencies are not reflective of what is actually there. For example, with the dBG frequency weighting, a measurement at 1 Hz is approximately 40 dB (!) lower than what is actually present in the environment.

4. Given the aforementioned, the authors of this Review consider any and all measurements expressed in dBG as immaterial to the issue of human health and infrasound exposure.

F. ANTHROPOGENIC *VERSUS* NATURAL INFRASOUND

1. The same issue with data resolution arises when comparisons are made between anthropogenic (human-made) "noise" sources and natural (planetary) sources.

2. Figure 10 is reproduced from the LUBW Report (Figure 8.2.1 on page 84) and shows the results of the measurements taken at different positions from the coast. Specifically, the purple-coloured curve shows the measurements taken on the beach, at 25 m from the water.

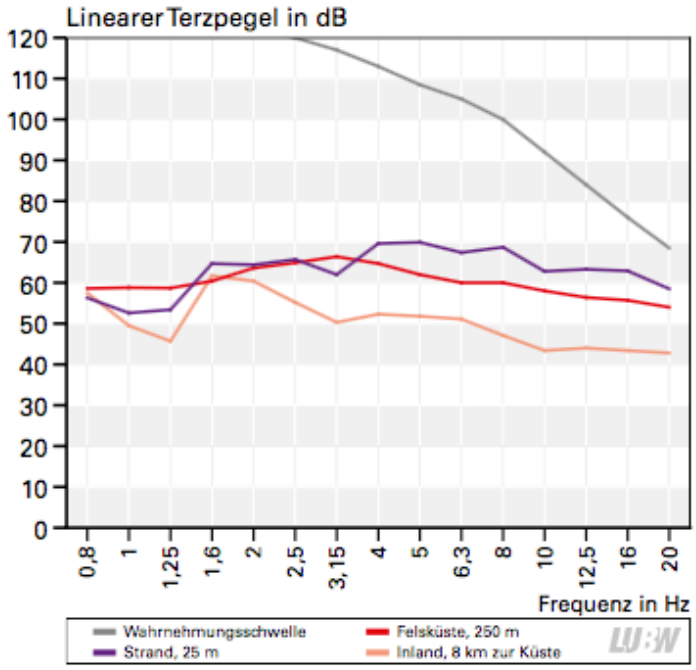

Figure 10. Reproduction of Figure 8.2.1. from the original LUBW Report (p.84), showing the acoustic data obtained at different position from the ocean. [*Strand* = Beach; *Felsküste* = Rocky coast*; Inland, 8 km zur Küste* = Inland, 8 km from the coast]

3. Figure 11 shows the measurement of ocean surf, with the microphone placed on the beach, at approximately 20 m from the water at 01:00, on 13 December 2016, in Denmark.

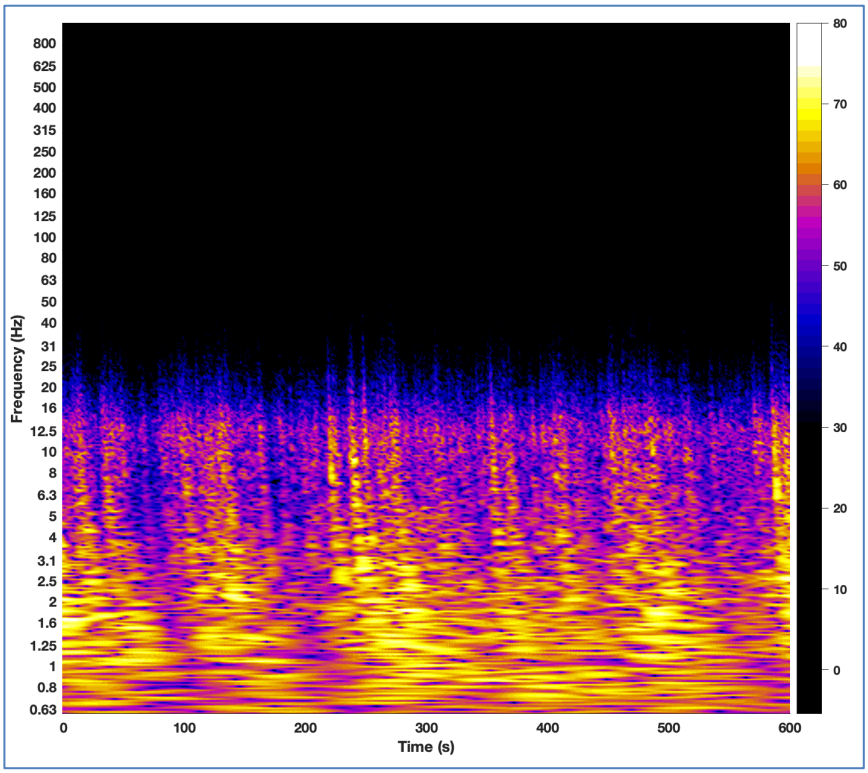

Figure 11. Sonogram of Romo Beach, Denmark on 13th December 2016, 01:10.

4. Figure 12 shows the same data but analyzed in ⅓-octave bands and expressed in dBLin.

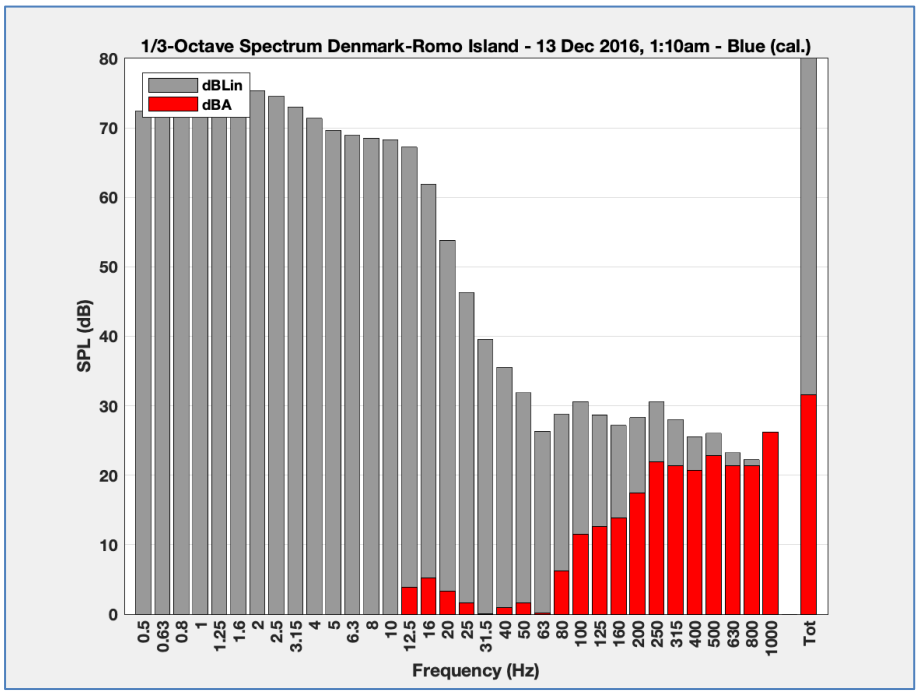

Figure 12. Spectrum analysis in ⅓-octaves for Romo Beach, Denmark on 13th December 2016 at 01:10.

5. The time scale of the peaks associated with the WT acoustic signature are of a different temporal scale than the peaks associated with natural phenomena.

6. The fact the peaks associated with the WT acoustic signature occur, exactly, at 1.3 seconds (blade pass frequency of 0.75 Hz) indicates that this can only be originating from a human-made machine, and not Nature.

7. This pulsed nature of the acoustic phenomena associated with WTs, with its particular temporal profile (1.3 seconds between peaks), has a particularly deleterious effect on biological systems.

G. CONCLUSIONS

1. The LUBW Report is based on the false premise:

   "what you can't hear, won't hurt you…"

2. There are other important scientific flaws in the LUBW Report, namely:

   - Low resolution of octave band analyses
   - Use of the dBG

3. These flaws have led to erroneous and misleading conclusions that are scientifically wrong, such as:

   Wind power plants make no significant contribution to [our infrasound environment] (Annex 1, page 9)

4. In reality, rotating WTs produce a well-known acoustic signature that translates into sequential peaks of elevated acoustic energy levels.

5. These peaks in acoustic energy levels are very well differentiated from wind and other naturally occurring acoustic phenomena.

6. The peaks associated with WT acoustic signatures have a significant effect on human biology because they present as a airborne waves of *pulsed* of acoustic energy.